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INATTENTION TO MARKET SHRINKAGE: THE CASE OF THE PHOTO FILM MARKET

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Inattention to market shrinkage: The case of the photo film market*

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Abstract

In the photo film market of the 2000s, Kodak's failure to sufficiently reduce production in response to market shrinkage has become a canonical example of how firms fail to adjust to market shrinkage. This seemingly optimistic response contrasts sharply with Fujifilm's response, which ultimately led it to exit the market successfully. To account for these contrasting cases, we incorporate the sparsity-based model of Gabaix (2014) into a textbook Cournot model in which firms are inattentive to changes in market size. We show that such inattention leads firms to respond optimistically to market shrinkage relative to the full-attention benchmark. We also show that a firm may respond pessimistically when its competitor is substantially inattentive. These results help explain Kodak's slow response and Fujifilm's relatively rapid adjustment to market shrinkage. Finally, we develop a model with endogenous attention choice, in which heterogeneity in forecast horizons and/or production cost structures generates heterogeneity in attention, a key driver of our results.

JEL Classification: D91, D21, L13

Keywords: Behavioral inattention, Declining industries, Oligopolistic markets

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1 Introduction

How do firms respond to changes in their market environment? The management literature has studied why established, industry-dominant firms often fail to adapt to industry transitions (e.g., Hamel and Prahalad (1996), Christensen (1997)). This literature argues that, although firms may recognize the need to adjust to changes in the market environment, their responses may nonetheless be insufficient. One reason for such failures is managerial cognition constrained by bounded rationality.[1] In parallel, the economics literature has developed models of inattention, in which boundedly rational agents may be inattentive to changes in their environment. Prominent examples include Gabaix (2014, 2019), who emphasize agents' inattention alongside their actions.[2]

In this paper, we adapt the sparsity-based model of inattention by Gabaix (2014) to a textbook Cournot model to study firms' responses to changes in the market environment. As a motivating example, we focus on the photo film market in the 2000s, in which two major producers—Eastman Kodak (hereafter Kodak) and Fuji Photo Film (hereafter Fujifilm)—remained active after the mid-2000s. Kodak's failure to adapt to market shrinkage is often cited as a canonical case in which even an established, industry-dominant firm did not respond adequately to a sustained decline in demand. By contrast, Fujifilm is widely viewed as having adapted more successfully to the same sustained decline in demand (e.g., Grant (2024, Chap. 12) and Vinokurova and Kapoor (2023)). We analyze these contrasting responses through the lens of inattention.

We begin by noting that demand for photo film declined sharply as digitization progressed (e.g., the diffusion of digital cameras). The photo film industry historically consisted of four major firms, but two of them exited in the mid-2000s. Kodak and Fujifilm remained in the market after the mid-2000s, with broadly comparable sales and market shares, yet their output responses to market shrinkage differed markedly. In particular, Fujifilm substantially reduced its output and shifted its focus away from photo film, whereas Kodak reduced its output only modestly. In hindsight, Kodak's response was overly optimistic given the magnitude of market shrinkage. One consequence of this failure to adjust was its bankruptcy filing on January 19, 2012.

[1] Zajac and Bazerman (1991) argue that managers may systematically overlook changes in the market environment and rivals' responses. Tripsas and Gavetti (2000) also provide empirical evidence on how managerial cognition contributes to organizational inertia.

[2] For a comprehensive survey of inattention models, see Gabaix (2019) (the sparsity-based models of inattention) and Maćkowiak, Matějka, and Wiederholt (2023) (the entropy-based models of inattention, often called rational inattention).

To analyze the contrasting output responses of two otherwise similar firms, we develop a Cournot model with inattention. To keep the exposition simple, we temporarily assume that each firm's degree of attention to market size is exogenously given and differs across firms. Using comparative statics, we show that attention determines how equilibrium quantities respond to a decline in market size. Relative to the full-attention benchmark, in which all firms are fully attentive, a firm with inattention reduces its output less, thereby exhibiting optimistic underreaction to a decline in market size. More specifically, equilibrium quantities depend on the configuration of the degrees of attention. Conversely, a firm may reduce its output by more than the full-attention benchmark, implying pessimistic overreaction. These responses are consistent with the contrasting output responses of Kodak and Fujifilm in our motivating example.

To explore the source of the difference in attention across firms, we introduce firm-specific forecast horizons over which firms predict the market size of their goods. We attribute differences in attention to differences in forecast horizons and augment the endogenous attention framework of Gabaix (2014, 2019) with forecast horizons. In general, full attention is not optimal. On the one hand, attention reduces perception bias about market size and thus lowers the associated loss of profits. On the other hand, paying attention is psychologically costly, which discourages firms from being fully attentive.

We show that a shorter forecast horizon leads firms to pay less attention to changes in market size. Our results imply that, even when firms face identical production cost and information structures, their responses to changes in market size can diverge systematically. If firms evaluate the future over different horizons, they may choose different degrees of attention to market size. In equilibrium, the resulting heterogeneity in attention influences firms' strategic quantity choices. If Fujifilm is forward-looking and Kodak is myopic, our model can capture their divergent responses in the photo film market in the 2000s.

Our model can be readily extended and generalized. We extend the baseline model to allow for alternative structures of production costs and alternative specifications of attention, and we also relax the duopoly assumption to allow for oligopoly. Using the extended model, we show that heterogeneity in production costs provides an additional channel for generating heterogeneity in attention. This mechanism may help explain why the seemingly less productive Agfa-Gevaert (hereafter Agfa) and Konica-Minolta (hereafter Konica) reduced photo film production earlier than

Kodak and Fujifilm in response to a decline in the size of the photo film market.

Our paper is closely related to the previous works in management, industrial organization, and macroeconomics. First, the management literature has long emphasized the importance of firms' attention and/or managerial cognition to the market environment (e.g., Thompson, Martin, and Scott (2023); Hamel and Prahalad (1996); Christensen (1997)).[3]

Second, there are two directions in the industrial organization literature that are related to our paper. The first direction discusses how firms adjust their decisions in response to market shrinkage. Ghemawat and Nalebuff (1985, 1990) develop Cournot models with market shrinkage. These works discuss how output capacity is strategically chosen by firms. More recently, Cetemen and Margaria (2024) study exit decisions in a stochastically declining industry. In their model, firms privately learn about the state of the industry through customer arrival rates and strategically choose exit decision. Our paper extends a stylized textbook Cournot model with inattention and investigates how firms adjust attention and output in a declining industry. In our model, firms' information set is common across firms, but the difference in attention to declines in market size affect otherwise symmetric firms' output decision.

The second direction in the industrial organization literature that is related to our paper focuses on inattention. The previous papers discuss how inattention from the consumer side is exploited by firms.[4] We also focus on inattention, but from the firm side. Like our paper, Cellini, Lambertini, and Ottaviano (2020) study firms' inattention in a Cournot model. However, they emphasize how the market structure is endogenously determined through firms' strategic choice of attention.[5]

Finally, the macroeconomic literature adapts the sparsity-based model of inattention by Gabaix (2014) to study underreaction in business cycles or consumption (e.g., Gabaix (2020, 2023)). Due to strategic substitution, our model can generate even overreaction to market shrinkage as well as underreaction. Relatedly, macroeconomic models under rational inattention of Sims (2003) and Maćkowiak and Wiederholt (2009) have been developed. The models share a similar spirit with the sparsity-based model of Gabaix (2014).[6] Likewise, Afrouzi (2024) extends rational inattention

[3]For instance, Hamel and Prahalad (1996) argues that many layoffs at large U.S. firms reflect senior management's failure to recognize and respond to changes in the market environment.

[4]Examples include Wilson (2010), Bordalo, Gennaioli, and Shleifer (2016), Cusumano, Fabbri, and Pieroth (2024), Gabaix and Laibson (2006), Janssen and Kasinger (2024), among others. See also Spiegler (2016) and Heidhues and Kőszegi (2018) for a survey of behavioral industrial organization.

[5]See also Pan (2024) who allows firms to choose the degree of attention continuously.

[6]See also Maćkowiak, Matějka, and Wiederholt (2023) and references therein.

to analyze strategic attention in an oligopolistic market.

The rest of the paper is organized as follows. Section 2 introduces the example of the photo film market in the 2000s to motivate our analysis. Section 3 presents the Cournot model extended with exogenous attention. In Section 4, we discuss the endogenous attention choice and characterize the optimal degree of attention. Section 6 concludes.

2 Motivating example: Photo film market

To motivate our analysis, this section concisely reviews competition in the photo film market from the mid-1990s through the early 2010s.

Figure 1 plots an index of global demand for color film reported in the *Fujifilm Integrated Report 2017*. Although the report does not disclose details of the underlying data, the plotted index covers the period from 1994 to 2011. Global demand increased steadily through the early 2000s, prior to the digital revolution, and peaked in 2001. However, with the diffusion of digital cameras, demand for photo film declined rapidly in the mid-2000s. These arguments are consistent with those in the previous studies by Lucas and Goh (2009), Kodama and Shibata (2016), and Ota (2020).[7]

[Figure 1 about here.]

Rapid decline in the global demand for photo film resulted in the production adjustment and the subsequent exit of major firms. During the 1990s, the industry was effectively dominated by four firms, Agfa, Fujifilm, Kodak, and Konica. Up to around 2000, these four firms accounted for roughly 95% of the global market share.[8] However, as demand fell sharply, Agfa spun off its film business in 2004 and effectively exited the market in 2005; Konica decided to withdraw in 2006 and completed its exit in 2007. By contrast, Kodak and Fujifilm maintained a presence in photo film after the mid-2000s, but their adjustment to the market shrinkage diverged markedly: Kodak struggled to diversify and ultimately filed for bankruptcy in 2012, whereas Fujifilm achieved successful diversification and dramatically reduced photo film production.

[7] Ota (2020) estimates demand curves for photo films in the US market and identifies changes in parameters in the demand function.

[8] See Gavetti, Henderson, and Giorgi (2003). Kaneko and Kajikawa (2025) also provides the more detailed description on the photo film industry during this period.

In 2005, Kodak and Fujifilm had comparable scale in their traditional film-related businesses, but also had the subsequent divergence in their sales. In 2005, the sales of the traditional film-related business of Kodak and Fujifilm were 2,841 million dollars and 2,223 million dollars, respectively. Thus, the sales and market share of the two companies in the global photo film market were comparable to each other.[9] Figure 2 plots the subsequent trend of sales from the traditional film-related businesses of Kodak and Fujifilm.[10] The solid line presents the US-dollar sales of Kodak's Film Products Group (FPG) segment where the value in 2005 is normalized to 100. The dashed line shows the Japanese-yen sales of Fujifilm's Imaging Solutions segment where the value in 2005 is again normalized to 100 for comparisons.[11] The figure indicates that the sales of both companies show a downward trend, but the speed of the decline differed significantly. From 2005 to 2011, Fujifilm's sales dropped 85%, while Kodak's sales dropped only 45%. The average rate of decline is 27.3% for Fujifilm and 9.6% for Kodak during this period. Kodak's sales even temporarily increased in 2008.[12] As such, Fujifilm's sales appear to decline sharply in line with the global demand decline shown in Figure 1, whereas Kodak's sales seem to fall much more slowly than the decline in global demand.[13]

[Figure 2 about here.]

3 Duopoly market model with inattention

In this section, we present a Cournot model with inattention. To keep the exposition simple, we begin by assuming that each firm's degree of attention is exogenously given and differs across firms and derive our first main result.

[9]See also Gavetti, Henderson, and Giorgi (2003), Ho and Chen (2018), among others.

[10]While the figure plots sales in the film and photofinishing segments for each firm, the products and services covered by these segments may differ slightly across the two firms. Kodak began reporting sales separately for digital and traditional film segments in 2006. Fujifilm also reported sales for photographic film and photofinishing systems separately in 2005. Because each firm applies different criteria when defining and separating products and services, segment coverage may not perfectly match.

[11]For Fujifilm's Imaging Solutions segment, we take the data of "color films and others" and "photofinishing equipment."

[12]The increase in Kodak's sales in 2008 may reflect the impact of changes in accounting methodology since Kodak reorganized its FPG segment into Film, Photofinishing and Entertainment Group (FPEG) segment in 2008. However, we confirm that the products and services included in both segments listed in the Kodak's annual report are not substantially different.

[13]Note that, even if we convert the Japanese-yen sales into the US-dollars, the Fujifilm's US-dollar sales continue to decline much more sharply than that of Kodak.

3.1 Setup

Consider a textbook Cournot model with two firms, 1 and 2. Each firm i ($i = 1, 2$) chooses its production quantity q_i, and total market quantity is $Q \equiv q_1 + q_2$. Firm i's profits are $\Pi_i = Pq_i - cq_i$, where P is the price and $c > 0$ is the constant marginal production cost common to both firms. The price P is determined by the following linear demand function:

$$Q = \alpha - \beta P, \tag{1}$$

where $\alpha > 0$ and $\beta > 0$. The parameter α represents the maximum demand when the price is zero. We therefore interpret α as the market size. A decrease in α shifts the demand curve inward by the same amount at every price. The parameter $\beta > 0$ captures the sensitivity of demand to the price. The corresponding inverse demand function is $P = a - bQ$, where $a \equiv \alpha/\beta$ and $b \equiv 1/\beta$.

We introduce behavioral firms in the spirit of Gabaix (2014, 2019) into the textbook Cournot model. We assume that firms are not fully attentive to the market size and partially adhere to a default value $\bar{\alpha}$. Following Gabaix (2014, 2019), we parameterize firm i's attention by $m_i \in [0, 1]$. In particular, firm i makes its quantity choice based on the subjectively perceived market size α_i^s, rather than the true α in (1):

$$\alpha_i^s(m_i, \alpha) = m_i\alpha + (1 - m_i)\bar{\alpha}. \tag{2}$$

Here, $m_i = 0$ means that the firm pays no attention to the true α and instead adheres to the default value $\bar{\alpha} > 0$. As Gabaix (2019) notes, the default value typically corresponds to the firm's prior belief. For simplicity, we assume that $\bar{\alpha}$ is common across firms. In contrast, $m_i = 1$ means full attention, as in the textbook Cournot model. Finally, if the default value coincides with the truth, $\bar{\alpha} = \alpha$, the model reduces to the textbook Cournot model.

One can also interpret $\bar{\alpha} - \alpha$ as a bias in subjective perception. Indeed, (2) can be rewritten as $\alpha_i^s(m_i, \alpha) = \alpha + (1 - m_i)(\bar{\alpha} - \alpha)$, so that the second term on the right-hand side represents a bias that distorts the perceived market size. In our model, the joint presence of inattention (i.e., $m_i < 1$) and perception bias (i.e., $\bar{\alpha} \neq \alpha$) is the key element driving our results.

Replacing α in (1) with $\alpha_i^s(m_i, \alpha)$ and defining $a_i^s(m_i, \alpha)$ as $a_i^s(m_i, \alpha) \equiv \alpha_i^s(m_i, \alpha)/\beta$, we obtain an "attention-augmented" (subjective) profit function for firm i:

$$\Pi_i^s = \big[a_i^s(m_i,\alpha) - b(q_i + q_j) - c\big]q_i, \tag{3}$$

where q_j denotes the quantity chosen by the other firm. It is important to distinguish Π_i^s from the true profit function, $\Pi_i = \big[a - b(q_i + q_j) - c\big]q_i$. In general, Π_i^s differs from Π_i because the former is based on the firm's subjective perception of market size and is therefore distorted relative to the true profit function.

Under its subjective perception, behavioral firm i maximizes the (distorted) profits in (3), taking q_j as given. The resulting reaction function is

$$q_i^s(m_i,\alpha) = \frac{a_i^s(m_i,\alpha) - c}{2b} - \frac{1}{2}q_j, \tag{4}$$

where q_i^s denotes firm i's optimal response under its subjective perception. The quantity decision depends on the degree of attention m_i. When $m_i = 1$, (4) reduces to the reaction function under full attention, $q_i^s(1,\alpha) = \frac{a-c}{2b} - \frac{1}{2}q_j$. Moreover, if the firm has no perception bias about market size (i.e., $\bar{\alpha} = \alpha$), then $\alpha_i^s(m_i,\alpha) = \alpha$ for any m_i, and the reaction function coincides with that under full attention.

3.2 Equilibrium

From the reaction function (4), the Cournot–Nash equilibrium is characterized by

$$q_i^*(m_i, m_j, \alpha) = \frac{2a_i^s(m_i,\alpha) - a_j^s(m_j,\alpha) - c}{3b}, \tag{5}$$

for any $(m_1, m_2) \in [0,1]^2$.

To analyze the motivating example in the previous section, we conduct comparative statics with respect to the market size parameter α. We define the full-attention benchmark as the equilibrium in which all firms are fully attentive. Comparing the equilibrium under inattention in (5) with this benchmark yields the following proposition.

Proposition 1. *Define thresholds $\hat{m}_i = \frac{1}{2} + \frac{1}{2}m_j$ and $\tilde{m}_i = \frac{1}{2}m_j$. (i) Relative to the full-attention benchmark (i.e., $m_1 = m_2 = 1$), firm i reduces its equilibrium quantity by a smaller amount in* *response to a decrease in α if $m_i < \hat{m}_i$ (optimistic response), and by a larger amount if $m_i > \hat{m}_i$ (pessimistic response). (ii) If $m_i < \tilde{m}_i$, then firm i's equilibrium quantity increases in response to a decrease in α.*

Proof. For (i), it suffices to show the optimistic response. Differentiating (5) with respect to α, we have $\frac{dq_i^*(m_i,m_j,\alpha)}{d\alpha} = \frac{2}{3}\left(m_i - \frac{1}{2}m_j\right)$. Under the full-attention benchmark, $\frac{dq_i^*(1,1,\alpha)}{d\alpha} = \frac{1}{3}$. If $m_i < \hat{m}_i = \frac{1}{2} + \frac{1}{2}m_j$, $\frac{dq_i^*(m_i,m_j,\alpha)}{d\alpha} < \frac{dq_i^*(1,1,\alpha)}{d\alpha}$. This implies that firm i underreacts to the decrease in α, relative to the full-attention benchmark. The underreaction to a decline in α leads to optimistic responses in q_i^* to declines in market size. For (ii), when $m_i < \tilde{m}_i = \frac{1}{2}m_j$, $\frac{dq_i^*(m_i,m_j,\alpha)}{d\alpha}$ becomes negative, meaning that q_i^* reacts in the opposite direction. □

Proposition 1 indicates that firm's inattention generates optimistic underreaction to a decline in market size, but it depends on the configuration of attention in the industry. By definition, $m_i < 1$ appears to generate a small reduction in response to a decline in market size. However, this is not a sufficient condition for optimistic underreaction. In fact, the equilibrium changes in firm i's quantity depends on firm j's degree of attention. The sufficient condition for underreaction relative to the full-attention benchmark is $m_i < \hat{m}_i = \frac{1}{2} + \frac{1}{2}m_j$ which ranges between 1/2 and 1. This is because firm i's equilibrium quantity is affected by firm j's attention, m_j, through firm j's quantity.

Figure 3 illustrates the relationship between the equilibrium quantity q_i^* and the market size parameter α under various configurations of attention.[14] The dash–dotted line corresponds to the full-attention benchmark in which both firms are fully attentive (i.e., $m_i = m_j = 1$). The remaining three lines correspond to cases in which at least one firm is inattentive. All lines intersect at $\alpha = \bar{\alpha}$. At this point, firms' equilibrium quantities coincide for all configurations of (m_i, m_j) because there is no perception bias about market size.

[Figure 3 about here.]

The figure indicates how the configuration of attention shape the response of equilibrium quantities to declines in market size. To simplify the discussion, suppose that initially $\alpha = \bar{\alpha}$ and then

[14] For other parameters, we set $\bar{\alpha} = 15$, $\beta = 1$, and $c = 3$, but the qualitative implications are robust to alternative parameter values.

α declines. The dashed line ($m_i = m_j = 0.5$) corresponds to a case in which $m_i < \hat{m}_i = \frac{1}{2} + \frac{1}{2}m_j$. Its slope is flatter than that under the full-attention benchmark, implying that firm i optimistically reduces its quantity by less than in the full-attention benchmark as α falls. In contrast, the solid line ($m_i = 1$ and $m_j = 0$) corresponds to a case in which m_i exceeds the threshold $\hat{m}_i$. Its slope is steeper than that under the full-attention benchmark, indicating that firm i pessimistically reduces q_i^* by more than in the benchmark. Finally, the dotted line corresponds to the case in which only firm i ignores changes in market size ($m_i = 0$ and $m_j = 1$). In this case, $m_i < \tilde{m}_i = \frac{1}{2}m_j$, so that q_i^* responds in the opposite direction: firm i's equilibrium quantity increases as α declines.

We next explore the mechanisms behind underreaction and overreaction in equilibrium quantities by focusing on the strategic interaction between the two firms. Figure 4 illustrates how the equilibrium shifts when market size declines from $\alpha(= \bar{\alpha})$ to $\alpha'(< \bar{\alpha})$.[15] In all panels of Figure 4, the solid and dashed lines depict the reaction functions of firms 1 and 2, respectively, when α equals the default value $\bar{\alpha}$. The dotted and dash–dotted lines depict the reaction functions of firms 1 and 2, respectively, after market size falls to α'. The pre-decline equilibrium is denoted by E, and the post-decline equilibrium by E'.

[Figure 4 about here.]

We compare the three equilibria discussed above with the full-attention benchmark, shown in panel (a) of Figure 4. Panel (b) presents the case of inattention to a decline in market size ($m_1 = m_2 = 0.5$). In this case, both firms underreact: relative to the full-attention benchmark, behavioral firms reduce their quantity by a smaller amount when market size falls.

In panels (c) and (d), firms take different actions in response to a decline in market size, depending on their degrees of attention. In panel (c), firm 1 is fully attentive ($m_1 = 1$), whereas firm 2 pays no attention ($m_2 = 0$). In this extreme case, firm 2's reaction function does not shift when market size declines. Taking firm 2's response as given, firm 1 then reduces its quantity sharply according to (4). As a result, firm 1's quantity overreacts relative to the full-attention benchmark. Panel (d) illustrates the opposite configuration: firm 1 pays no attention ($m_1 = 0$) while firm 2 is fully attentive ($m_2 = 1$). In this case, firm 2 reduces quantity sharply in response to the decline in market size. Taking firm 2's response as given, firm 1 increases its quantity rather

[15] In the figure, we set $\bar{\alpha} = 15$ and $\alpha' = 10$.

than reducing it. Here, firm 1's equilibrium quantity rises when α falls because firm 2's seemingly pessimistic overreaction substantially depresses total market quantity, creating room for firm 1 to expand.

In summary, these panels illustrate how firms' attention critically shapes the Cournot equilibrium. As panels (b), (c), and (d) show, inattention can generate equilibria featuring underreaction, overreaction, or even responses in the "wrong" direction relative to the change in market size.

The difference in firms' responses to a decline in market size may help explain the contrasting cases of Kodak and Fujifilm discussed in the previous section (see Figure 2). Figure 5 illustrates how declines in market size from the initial value of $\bar{\alpha}$ affect the equilibrium sales, $P^* q_i^*$ for $i = 1, 2$, where P^* denotes the equilibrium price. For simplicity, we assume that firm 1 (Kodak) is completely inattentive to α ($m_1 = 0$), whereas firm 2 (Fujifilm) is fully attentive ($m_2 = 1$). Figure 5 is qualitatively consistent with Figure 2: firm 1's (Kodak's) sales do not decline substantially, while firm 2's (Fujifilm's) sales decline markedly.

[Figure 5 about here.]

As anecdotal evidence, Komori (2015), the former CEO of Fujifilm, emphasizes the role of managerial cognition during periods of rapid market shrinkage. Reflecting on Fujifilm's experience, he notes that although quantitative indicators clearly suggested that the photo film market was likely to nearly disappear, many executives were constrained by preconceptions, for example, the conviction that "this just can't be happening" or that "a market this big can't possibly be shrinking." This account suggests that relaxing reliance on such prior beliefs, that is, placing greater weight on the true market size (a higher m_i in our notation), may have been an important factor behind Fujifilm's successful adjustment to the changing market environment.

4 Endogenous attention

In this section, we explore a source of differences in m_i across firms. To this end, we attribute it to different forecast horizons regarding market size and extend the framework of the endogenous attention choice in Gabaix (2014, 2019).

4.1 Setup

Consider a finite-horizon, multi-period model in which firms repeatedly play a static game over $t = 1, 2, \ldots, T$. In each period, the static game is identical to the textbook Cournot model described in the previous section, except that market size follows the stochastic process

$$\alpha_t = \alpha_{t-1} + \varepsilon_t, \tag{6}$$

where $\varepsilon_t \sim i.i.d.\ (0, \sigma^2)$ and $\alpha_0 > 0$ is given.[16] Market size α_t is exogenous to firms. That is, although market size varies over time, it is unaffected by past attention choices or past quantity decisions of either firm.

Under this extension, the demand function (1) is replaced by

$$Q_t = \alpha_t - \beta P_t, \tag{7}$$

for $t = 1, 2, \ldots, T$. The corresponding inverse demand function is $P_t = a_t - bQ_t$, where $a_t \equiv \alpha_t/\beta$.

Within each period, the timing is as follows. At the beginning of period t, each firm chooses its degree of attention m_{it} before the realization of market size α_t. After α_t is realized, firms simultaneously choose quantities q_{it}, taking the predetermined attention choices m_{it} as given. Firms cannot revise their attention after observing α_t. Given m_{it}, firms form subjective perceptions of market size and then determine their optimal quantities. This assumption means that firms cannot fully adjust to $\Delta\alpha_t = \varepsilon_t$ since they pay only partial attention.

A few remarks are in order. First, period-by-period profits are assumed to be independent of past attention and quantity choices. Moreover, for each $(m_{it}, m_{jt}) \in [0, 1]^2$, the static game has a unique Nash equilibrium. Thus, with a finite horizon T, the outcome of the repeated interaction is given by the sequence of static-game Nash equilibria in every period, which constitutes a subgame-perfect equilibrium; in particular, tacit collusion cannot emerge.[17]

Second, we can show that the optimal attention choice is also time-invariant as long as each firm's forecast horizon for evaluating profits is time-invariant and (6) does not influence the demand

[16] To maintain consistency with our model in Section 3, we assume that α_0 is positive and sufficiently large and σ^2 is sufficiently small so that equilibrium quantities remain strictly positive for all t.

[17] See Belleflamme and Peitz (2015) for details.

sensitivity parameter β. To simplify notation, we therefore omit the time subscript on m_{it} and write it as m_i in what follows.

4.2 The objective function for choosing attention

To model the endogenous attention choice, we adopt the "sparse max" approach of Gabaix (2014, 2019). In this approach, economic agents choose attention to minimize the loss induced by inattention, subject to a psychic cost of paying attention.[18] In our setting, firms raise their degree of attention until the marginal reduction in the loss of profits from inattention is exactly balanced by the marginal increase in the psychic cost of attention.

The loss from inattention is defined as the difference between firm i's true period-by-period profits when it chooses the (subjectively) optimal quantity under inattention and when it chooses the corresponding quantity under full attention:

$$\begin{aligned} L(m_i, \alpha_t) &\equiv \Pi_i(q_i^s(m_i, \alpha_t)) - \Pi_i(q_i^s(1, \alpha_t)) \\ &= -\frac{1}{4\beta}(1 - m_i)^2(\bar{\alpha}_t - \alpha_t)^2. \end{aligned} \tag{8}$$

Note that Π_i in (8) denotes the *true* period-by-period profits, not the subjective profits Π_i^s in (3). Thus, $L(m_i, \alpha_t)$ measures the loss of profits from choosing quantity under inattention relative to that under full attention.

The second equality shows that $L(m_i, \alpha_t)$ is quadratic in perception bias $\bar{\alpha}_t - \alpha_t$.[19] Here, $\bar{\alpha}_t$ denotes the default value in period t. In deriving (8), firm i takes firm j's quantity as given. Any effect of q_{jt} on firm i's profits is common to both $\Pi_i\left(q_i^s(m_i, \alpha_t)\right)$ and $\Pi_i\left(q_i^s(1, \alpha_t)\right)$ and therefore cancels out. For the same reason, firm j's attention choice m_j does not enter $L(m_i, \alpha_t)$: m_j affects firm i's profits only through q_{jt}, whose contribution is differenced out in the loss function.

Equation (8) implies that the loss of profits from inattention increases with the perception bias $\bar{\alpha}_t - \alpha_t$ and decreases with attention $m_i \in [0, 1]$. In particular, full attention ($m_i = 1$) eliminates

[18] As Gabaix (2014) notes, the approach and its implications are closely related to rational inattention models (e.g., Sims 2003; Maćkowiak, Matějka, and Wiederholt 2023), in which agents acquire signals about fundamentals and reduce uncertainty subject to an information-capacity constraint, typically formulated in terms of entropy-based mutual information.

[19] See Appendix A.1. In the sparse-max approach of Gabaix (2014, 2019), the loss from inattention is obtained from a second-order approximation of the objective function. In our setting, the profit function is quadratic, so no approximation is required.

the loss, yielding $L(m_i, \alpha_t) = 0$. The loss is also decreasing in the demand sensitivity parameter β. Intuitively, a smaller β corresponds to a steeper inverse demand curve (a larger $b = 1/\beta$), so profits are more sensitive to quantity choices and hence to misperceptions about market size. As a result, reductions in profits caused by inattention are larger as β decreases.

We are now ready to specify firm i's problem of choosing attention. Let $H_i > 0$ denote firm i's forecast horizon. The psychic cost of attention is given by $(d/2)m_i^2$, where the parameter $d \geq 0$. At the beginning of period t, firm i chooses m_i by minimizing the expected loss from inattention over the next H_i periods, net of the (per-period) psychic cost:

$$\min_{m_i \in [0,1]} \sum_{\tau=0}^{H_i - 1} \mathbb{E}_{t-1} \left[\frac{1}{4\beta} (\bar{\alpha}_{t+\tau} - \alpha_{t+\tau})^2 (1 - m_i)^2 + \left(\frac{d}{2} \right) m_i^2 \right], \tag{9}$$

for $t = 1, 2, \ldots, T - (H_i - 1)$. We assume that T is sufficiently large and that $H_i \neq H_j$, so that the two firms may optimally choose different attention levels, $m_i \neq m_j$.[20] Using (6), we rewrite (9) as

$$\min_{m_i \in [0,1]} \frac{1}{4\beta} \left[\frac{H_i(H_i + 1)\sigma^2}{2} \right] (1 - m_i)^2 + H_i \left(\frac{d}{2} \right) m_i^2, \tag{10}$$

where we assume that the default value of the market size parameter is given by $\bar{\alpha}_{t+\tau} = \mathbb{E}_{t-1}\alpha_{t+\tau} = \alpha_{t-1}$ for any $\tau \geq 0$, the prior mean at the end of period $t - 1$. Moreover, (6) implies that $\mathbb{E}_{t-1}\big(\alpha_{t-1} - \alpha_{t+\tau}\big)^2 = \mathrm{Var}_{t-1}(\sum_{k=0}^{\tau} \varepsilon_{t+k}) = (\tau + 1)\sigma^2$, since ε_t are i.i.d. with variance σ^2. Therefore, $\sum_{\tau=0}^{H_i - 1} \mathbb{E}_{t-1}\big(\bar{\alpha}_{t+\tau} - \alpha_{t+\tau}\big)^2$ simplifies to the term in brackets in (10), $\frac{H_i(H_i+1)}{2}\sigma^2$.

The optimization problem in (10) can also be written (up to a positive multiplicative constant) as the following minimization problem:

$$\min_{m_i \in [0,1]} \frac{H_i + 1}{4\beta} \sigma^2 (1 - m_i)^2 + d m_i^2. \tag{11}$$

The first-order condition yields the optimal degree of attention:

$$m_i^* = \frac{(H_i + 1)\sigma^2}{(H_i + 1)\sigma^2 + 4\beta d} \in (0, 1]. \tag{12}$$

[20] When $t > T - (H_i - 1)$, the horizon H_i exceeds the remaining number of periods. In that case, (9) can be modified by replacing the upper bound $H_i - 1$ with $T - t$, and by replacing $H_i \times (d/2)m_i^2$ with $(T - t + 1) \times (d/2)m_i^2$. This implies that attention choices become independent of H_i near the terminal date, and, in particular, the two firms' attention choices coincide when both are sufficiently close to the end of the game. Hence, to focus on differences in attention driven by differences in horizons, we impose a sufficiently large T and $H_i \neq H_j$.

4.3 Characterizing the optimal degree of attention

We characterize m_i^* in the following proposition.

Proposition 2. *Firm i's optimal degree of attention m_i^* is determined by the exogenous parameters H_i, σ^2, d, and β. In particular, m_i^* is increasing in the forecast horizon H_i and in the volatility of variations in market size σ^2, and decreasing in the psychic cost parameter d and in the demand sensitivity parameter β.*

Proposition 2 reflects that firms pay attention to α_t to mitigate the loss of profits arising from uncertainty about current and future market conditions. A longer forecast horizon amplifies the cumulative uncertainty relevant for profits, increasing the expected loss from inattention and therefore inducing more attention. Similarly, when market-size variations are more volatile, the expected loss of misperceiving α_t is larger, leading firms to allocate more attention to market size.

The optimal degree of attention is also affected by d and β. A smaller d lowers the marginal psychic cost of attention and therefore induces firms to pay more attention. Likewise, a smaller β (equivalently, a steeper inverse demand curve) makes profits more sensitive to quantity choices and hence increases the marginal loss from deviations of m_i from unity. When the loss of profits becomes more sensitive to m_i, firms have stronger incentives to allocate attention in order to avoid this loss.

Importantly, the qualitative results in Section 3 continue to hold when attention is endogenized. Given (m_1^*, m_2^*), the static game repeated in each period consists of a unique Nash equilibrium. With a finite period T, the outcome of the repeated interaction is therefore characterized by the sequence of these Nash equilibria, and equilibrium quantities can be written as $q_i^*(m_i^*, m_j^*, \alpha_t)$, where the functional form is given by (5).

Our model with endogenous attention suggests that differences in forecast horizons between Kodak and Fujifilm could be a source of their contrasting responses to market shrinkage. In this extension, the only ex ante difference between the two firms is their forecast horizon H_i, which endogenously generates different degrees of attention and, in turn, different reaction functions in quantity competition. The key implication in this case is that differences in forecast horizons alone can generate seemingly optimistic underreaction and/or pessimistic overreaction, even when firms face the same change in market size.

5 Extension

This section shows that our model can be readily extended to derive additional predictions. Specifically, we extend it to allow for (i) an N-firm Cournot oligopoly; (ii) inattention to the demand sensitivity parameter β; and (iii) heterogeneous marginal production costs. As before, we begin with a Cournot model in which attention is exogenously given and use this setup to illustrate robustness to alternative interpretations of market size. We then allow firms to choose attention and show that heterogeneity in marginal production costs generates heterogeneity in attention. This mechanism may help explain why Agfa and Konica reduced their production earlier than Kodak and Fujifilm when the market shrank.

5.1 The extended model with exogenous attention

Consider an oligopolistic market with N firms, in which the total market quantity is $Q = \sum_{i=1}^{N} q_i$. In addition, we assume that firms pay only partial attention to β (rather than α) and their marginal production costs (denoted by c_i) are heterogeneous.

The subjectively perceived demand sensitivity $\beta_i^s(m_i, \beta)$ is given by

$$\beta_i^s(m_i, \beta) = m_i\beta + (1 - m_i)\bar{\beta}, \qquad m_i \in [0, 1], \tag{13}$$

where $\bar{\beta}$ denotes a default value of β that is common across firms.

We emphasize that a rise in β provides an alternative interpretation of a decline in market size. To see this, recall that the parameters in the inverse demand function (i.e., $P = a - bQ$) are defined as $a = \alpha/\beta$ and $b = 1/\beta$. When β rises, the inverse demand function not only becomes flatter in slope but also has a lower intercept. In this sense, a higher β not only makes demand prices less responsive but also reduces market size.[21]

Under the subjective perception (13), behavioral firm maximizes the distorted profits, taking $q_{-i} \equiv Q - q_i$ as given. The reaction function for firm i is:

$$q_i^s(m_i, \beta) = \frac{\alpha - \beta_i^s c_i}{2} - \frac{1}{2} q_{-i}, \tag{14}$$

[21] Vives (2002) defines a decline in market size as an independent increase in b holding the intercept constant. While our definition differs from Vives (2002), we can easily examine changes in market size as defined there in the same way.

where $q_i^s(m_i, \beta)$ is firm i's optimal response under the subjective perception (13).[22] When $m_i = 1$, (14) reduces to $q_i^s(1, \beta) = \frac{\alpha - \beta c_i}{2} - \frac{1}{2}q_{-i} = \frac{a - c_i}{2b} - \frac{1}{2}q_{-i}$. Furthermore, without perception bias about β, the reaction function coincides with that under full attention.

The Cournot–Nash equilibrium is characterized by:

$$q_i^*(\boldsymbol{m}, \beta) = \frac{\alpha - N\beta_i^s c_i + \sum_{j \neq i} \beta_j^s c_j}{1 + N}, \tag{15}$$

where $\boldsymbol{m} = (m_1, m_2, \ldots, m_N) \in [0, 1]^N$.

We are now ready to discuss the comparative statics with respect to β.

Proposition 3. *Define thresholds*

$$\hat{m}_i \equiv 1 - \frac{1}{Nc_i} \sum_{j \neq i} c_j + \frac{1}{Nc_i} \sum_{j \neq i} m_j c_j, \qquad \tilde{m}_i \equiv \frac{1}{Nc_i} \sum_{j \neq i} m_j c_j. \tag{16}$$

(i) Relative to the full-attention benchmark (i.e., $m_1 = \cdots = m_N = 1$), firm i reduces its equilibrium quantity by a smaller amount in response to an increase in β if $m_i < \hat{m}_i$ (optimistic response), and by a larger amount if $m_i > \hat{m}_i$ (pessimistic response). (ii) If $m_i < \tilde{m}_i$, then firm i's equilibrium quantity increases in response to an increase in β.

Proof. See Appendix A.2.

Proposition 3 generalizes Proposition 1 when $N = 2$ and $c_i = c$ for $i = 1, 2$. Note that, while the object of attention differs from α, the conditions for optimistic underreaction, for pessimistic overreaction and for a response in the opposite direction are the same under this special case.

As discussed in Proposition 1, optimistic underreaction to a decline in market size depends on the configuration of attention in the industry. Again, $m_i < 1$ is not the sufficient condition for optimistic underreaction. The sufficient condition for underreaction relative to the full-attention benchmark is $m_i < \hat{m}_i \leq 1$ because the equilibrium changes in firm's quantity depends on the degree of attention by other firms.[23]

The threshold $\hat{m}_i$ increases with competitors' attention, implying that optimistic underreaction

[22] We may express the reaction function in terms of a^s and b^s, as in (2). Here, we use the formulation in (13) to emphasize which parameter firms are inattentive to.

[23] We can easily show that $\hat{m}_i \in (-\infty, 1]$. This implies that the sufficient condition for underreaction is more stringent than $m_i < 1$.

becomes more likely as rivals pay more attention. The effect of other firms' attention on the threshold depends on relative marginal production costs, c_j/c_i. In particular, optimistic underreaction by firm i is more likely when a rival's productivity relative to firm i's is lower (i.e., when c_j/c_i is higher).

5.2 Endogenous attention in the extended model

We next allow firms to choose attention. In Section 4, only a source of difference in the degree of firms' attention is the difference in forecast horizon. With this extension, we explore how the firm's productivity (represented by marginal production cost) determines the degree of attention as an additional determinant of attention.

Let β_t follow the stochastic process of the form:

$$\beta_t = \beta_{t-1} + \varepsilon_t, \tag{17}$$

where $\beta_0 > 0$ is given and $\varepsilon_t \sim i.i.d.\left(0, \sigma^2\right)$. Here, with some abuse of notation, we denote the shock to β_t by ε_t and its variance by σ^2.[24] In addition, the demand function is replaced by $Q_t = \alpha - \beta_t P_t$.

The (period-by-period) loss from inattention to β_t can quadratically be approximated around at the default value of $\bar{\beta}_t$:

$$L(m_{it}, \beta_t) \approx -\frac{c_i^2}{4\bar{\beta}_t}(1 - m_{it})^2(\bar{\beta}_t - \beta_t)^2, \tag{18}$$

where $\bar{\beta}_t$ is the default value of β_t in period t. As in Section 4, we assume that $\bar{\beta}_t$ is the prior mean before observing β_t. More importantly, the equation for $L(m_{it}, \beta_t)$ (i.e., (18)) indicates that the loss from inattention depends on firm i's marginal production cost. This sharply contrasts with the equation for $L(m_i, \alpha_t)$ (i.e., (8)).

At the beginning of period t, a firm with forecast horizon H_i chooses $m_{it} \in [0, 1]$ to minimize the expected loss from inattention over the next H_i periods, net of the psychic cost. Given the information available at period $t-1$ and (17), we specify the default value as $\bar{\beta}_{t+\tau} = \mathbb{E}_{t-1}\beta_{t+\tau} =$

[24] As in the specification of α_t, we assume that the variance σ^2 is sufficiently small to ensure a strictly positive β_t for all t.

β_{t-1}. Then, the expected loss from inattention over the next H_i periods is

$$\min_{m_{it}\in[0,1]} \sum_{\tau=0}^{H_i-1} \mathbb{E}_{t-1}\left[\frac{c_i^2}{4\beta_{t-1}}(\beta_{t-1}-\beta_{t+\tau})^2(1-m_{it})^2+\left(\frac{d}{2}\right)m_{it}^2\right], \tag{19}$$

for $t = 1, 2, ..., T - (H_i - 1)$.

As we discussed in Section 4, the above minimization problem can also be simplified to minimizing $\frac{c_i^2(H_i+1)}{4\beta_{t-1}}\sigma^2(1-m_{it})^2+dm_{it}^2$. The first-order condition yields the optimal degree of attention m_{it}^* similar to (12):

$$m_{it}^* = \frac{c_i^2(H_i+1)\sigma^2}{c_i^2(H_i+1)\sigma^2+4\beta_{t-1}d} \in (0,1]. \tag{20}$$

The following proposition characterizes m_{it}^* under the extended model.

Proposition 4. *Firm i's optimal degree of attention m_{it}^* is determined by the exogenous parameters H_i, σ^2, and d as the optimal degree of attention in Proposition 2. In addition, m_{it}^* is affected by the firm's marginal production costs c_i and the demand sensitivity parameter in the previous period β_{t-1}. In the extended model, m_{it}^* is increasing in c_i and heterogeneous across firms due to c_i. It is decreasing in β_{t-1} and time-varying due to β_{t-1} .*

Proposition 4 generalizes Proposition 2. While changes in α_t suggests changes in market size through the intercept of the inverse demand function, those in β_t are interpreted as changes in market size through the intercept *and* the slope. In Proposition 4, the optimal degree of attention m_{it}^* depends on firm i through marginal production costs c_i and time t through β_{t-1}. Recall that contrasting output responses critically depend on whether m_i is heterogenous. The dependence of m_{it}^* on c_i suggests that, even if the firm's forecast horizons happen to be equal each other (e.g., $H_i = 1$), there is still an alternative source for heterogeneity in attention. Furthermore, the optimal degree of attention depends on the historical observations of ε_t. When past positive shock to β_{t-1} makes the market size small (i.e., makes β_{t-1} large), the loss from inattention to β_t becomes small and m_{it}^* becomes low. If β_t further increases with $\varepsilon_t > 0$, firm i's attention further decreases in the next period. In this case, the firm becomes more inattentive to β_t.

The presence of multiple sources for heterogeneity in m_{it}^* also suggests that the determinants of the degree of attention should be assessed in multiple dimensions. While the model in Section 4 attributes the difference in m_i^* to the differences in forecast horizon H_i, the extended model introduces an additional source of heterogeneity stemming from heterogeneity in productivity, represented by marginal production costs. In particular, less productive firms pay more attention to β_t and thus adjust their quantities more quickly. This model's prediction may be relevant for the photo film market: In the early 2000s, we observe the early exit of Agfa and Konica whose market shares are relatively low perhaps due to low productivity. If these two firms could be interpreted as less productive firms, their early exit from the photo film market may be interpreted as a result of more attention to declines in market size (relative to Kodak and Fujifilm). By contrast, if Kodak and Fujifilm were of comparable scale and therefore had only limited productivity differences, the differences in forecast horizons may play a larger role in accounting for heterogeneity in m^*_{it}. Identifying these multiple sources is ultimately an empirical question and calls for a broader empirical analysis.

6 Conclusion

This paper examines how firms respond to changes in the market environment when they are inattentive. By incorporating the sparsity-based model of inattention into a textbook Cournot model, we show that inattention to a decline in market size may lead firms to respond overly optimistically relative to the full-attention benchmark. We also show that strategic interaction can generate the opposite response: when one firm is substantially inattentive, its rival may respond more pessimistically. Finally, we demonstrate that heterogeneity in forecast horizons and production cost structures can generate heterogeneity in attention by firms, helping explain why firms facing the same shrinking market may adjust at different speeds.

Several questions remain for future research. One is to examine these mechanisms empirically using firm-level evidence on attention. Another is to extend the model to richer settings with exit and/or innovation. It would also be interesting to model inattention from both consumer and firm sides and to explore how they interact with each other.

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A Appendix

A.1 Derivation of the loss from inattention to α

Define the reaction function under full attention as

$$q_i^r \equiv q_i^s(1, \alpha).$$

For notational simplicity, we suppress the time subscript t in this appendix, as the loss depends only on within-period variables.

Firm i's loss function from inattention to α is given by

$$\begin{aligned} L(m_i, \alpha) &\equiv \Pi_i(q_i^s(m_i, \alpha)) - \Pi_i(q_i^r) \\ &= [a - b(q_i^s + q_j) - c]q_i^s - [a - b(q_i^r + q_j) - c]q_i^r \\ &= (a - c - bq_j)(q_i^s - q_i^r) - b(q_i^s + q_i^r)(q_i^s - q_i^r). \end{aligned} \tag{21}$$

From (4),

$$\begin{aligned} q_i^s + q_i^r &= \left[\frac{a_i^s - c}{2b} - \frac{1}{2}q_j\right] + \left[\frac{a - c}{2b} - \frac{1}{2}q_j\right] \\ &= \frac{a_i^s + a}{2b} - \frac{c}{b} - q_j, \end{aligned} \tag{22}$$

and

$$\begin{aligned} q_i^s - q_i^r &= \left[\frac{a_i^s - c}{2b} - \frac{1}{2}q_j\right] - \left[\frac{a - c}{2b} - \frac{1}{2}q_j\right] \\ &= \frac{a_i^s - a}{2b}. \end{aligned} \tag{23}$$

Substituting (22) into (21),

$$
\begin{aligned}
L(m_i, \alpha) &= (a - c - bq_j)(q_i^s - q_i^r) - b\left(\frac{a_i^s + a}{2b} - \frac{c}{b} - q_j\right)(q_i^s - q_i^r) \\
&= (a - c - bq_j)(q_i^s - q_i^r) - \left(\frac{a_i^s + a}{2} - c - bq_j\right)(q_i^s - q_i^r) \\
&= \left(a - \frac{a_i^s + a}{2}\right)(q_i^s - q_i^r) = -\frac{1}{2}(a_i^s - a)(q_i^s - q_i^r). \qquad (24)
\end{aligned}
$$

Using (23) in (24) gives

$$
L(m_i, \alpha) = -\frac{1}{2}(a_i^s - a)\left(\frac{a_i^s - a}{2b}\right) = -\frac{1}{4b}(a_i^s - a)^2. \qquad (25)
$$

Finally, noting that $a = b\alpha$, $a_i^s = b\alpha_i^s$, and $\alpha_i^s = m_i\alpha + (1 - m_i)\bar{\alpha}$, we obtain (8):

$$
\begin{aligned}
L(m_i, \alpha) &= -\frac{1}{4b}[b(\alpha_i^s - \alpha)]^2 = -\frac{b}{4}(\alpha_i^s - \alpha)^2 \\
&= -\frac{b}{4}\left[(1 - m_i)(\alpha - \bar{\alpha})\right]^2 \\
&= -\frac{1}{4\beta}(1 - m_i)^2(\alpha - \bar{\alpha})^2. \qquad (26)
\end{aligned}
$$

A.2 Derivation of Proposition 3

Differentiating the quantity in equilibrium (15) with respect to β and the full-attention benchmark, we have

$$
\frac{dq_i^*(\boldsymbol{m}, \beta)}{d\beta} = -\frac{N}{1+N}\left(c_i m_i - \frac{1}{N}\sum_{j \neq i} c_j m_j\right), \qquad (27)
$$

$$
\frac{dq_i^*(\mathbf{1}, \beta)}{d\beta} = -\frac{N}{1+N}\left(c_i - \frac{N-1}{N}\sum_{j \neq i} c_j\right). \qquad (28)
$$

A comparison of (27) and (28) yields the thresholds $\hat{m}_i$ defined in Proposition 3. Likewise, arranging (27) yields the threshold $\tilde{m}_i$.

A.3 Derivation of the loss from inattention to β

Define the reaction function under full attention as

$$q_i^r \equiv q_i^s(1, \beta).$$

As in Section A.1, we suppress the time subscript t.

The loss function from inattention to β is given by

$$\begin{aligned}
L(m_i, \beta) &\equiv \Pi_i(q_i^s(m_i, \beta)) - \Pi_i(q_i^r) \\
&= \left[\frac{\alpha}{\beta} - \frac{1}{\beta}(q_i^s + q_j) - c_i\right] q_i^s - \left[\frac{\alpha}{\beta} - \frac{1}{\beta}(q_i^r + q_j) - c_i\right] q_i^r \\
&= \left(\frac{\alpha}{\beta} - c_i - \frac{q_j}{\beta}\right)(q_i^s - q_i^r) - \frac{1}{\beta}(q_i^s + q_i^r)(q_i^s - q_i^r). \qquad (29)
\end{aligned}$$

From (14),

$$q_i^s + q_i^r = \alpha - \frac{c_i(\beta_i^s + \beta)}{2} - q_j, \qquad (30)$$

and

$$q_i^s - q_i^r = -\frac{c_i}{2}(\beta_i^s - \beta). \qquad (31)$$

Substituting (30) into (29) yields

$$\begin{aligned}
L(m_i, \beta) &= \left(\frac{\alpha}{\beta} - c_i - \frac{q_j}{\beta}\right)(q_i^s - q_i^r) \\
&\quad - \frac{1}{\beta}\left(\alpha - \frac{c_i(\beta_i^s + \beta)}{2} - q_j\right)(q_i^s - q_i^r) \\
&= \left(\frac{c_i \beta_i^s}{2\beta} - \frac{c_i}{2}\right)(q_i^s - q_i^r) \\
&= \frac{c_i}{2\beta}(\beta_i^s - \beta)(q_i^s - q_i^r). \qquad (32)
\end{aligned}$$

Using (31), we have

$$
\begin{aligned}
L(m_i, \beta) &= \frac{c_i}{2\beta}(\beta_i^s - \beta)\left[-\frac{c_i}{2}(\beta_i^s - \beta)\right] \\
&= -\frac{c_i^2}{4\beta}(\beta_i^s - \beta)^2.
\end{aligned} \tag{33}
$$

Since

$$
\beta_i^s = m_i\beta + (1 - m_i)\bar{\beta},
$$

the exact period loss is

$$
\begin{aligned}
L(m_i, \beta) &= -\frac{c_i^2}{4\beta}\left[(1 - m_i)(\beta - \bar{\beta})\right]^2 \\
&= -\frac{c_i^2}{4\beta}(1 - m_i)^2(\beta - \bar{\beta})^2.
\end{aligned} \tag{34}
$$

Following the sparse-max framework, we approximate (34) around the default value $\bar{\beta}$. The quadratic approximation of the loss function around $\beta = \bar{\beta}$ (18) is

$$
L(m_i, \beta) \approx -\frac{c_i^2}{4\bar{\beta}}(1 - m_i)^2(\beta - \bar{\beta})^2. \tag{35}
$$

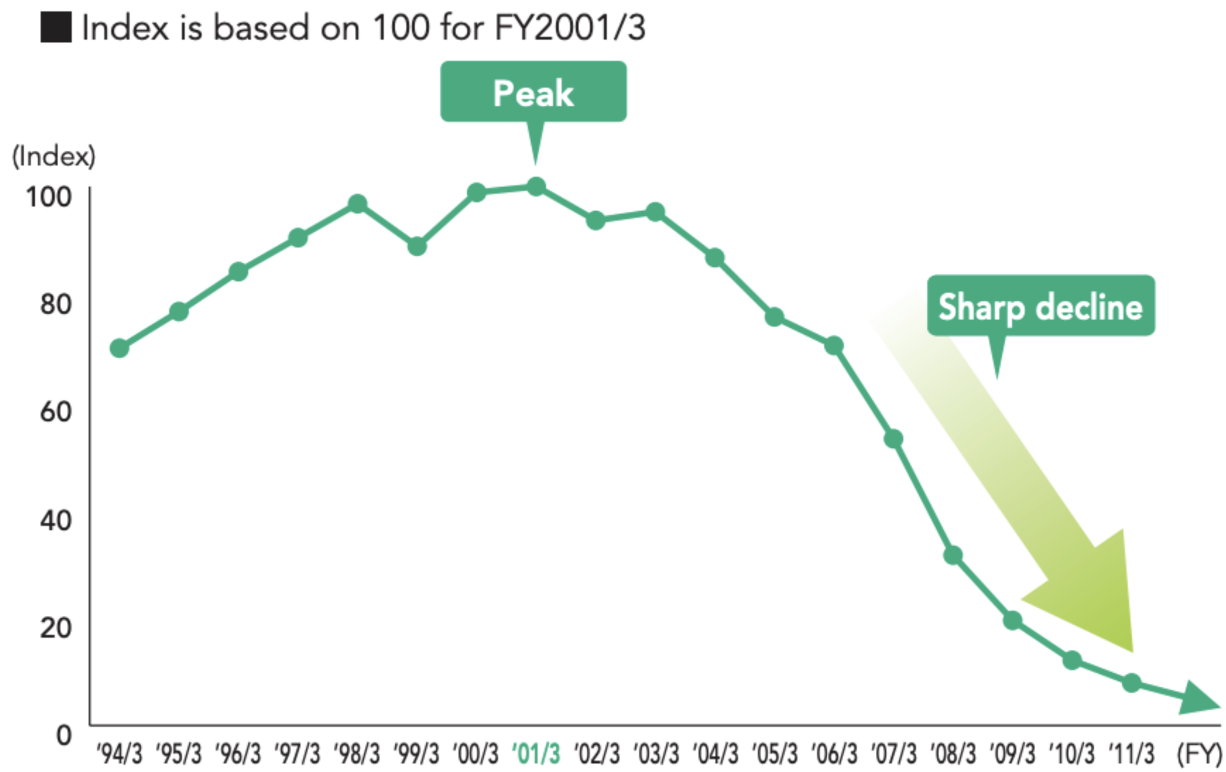

Figure 1: The index of the global demand for color film

Note: The data source is *Fujifilm Integrated Report 2017*.

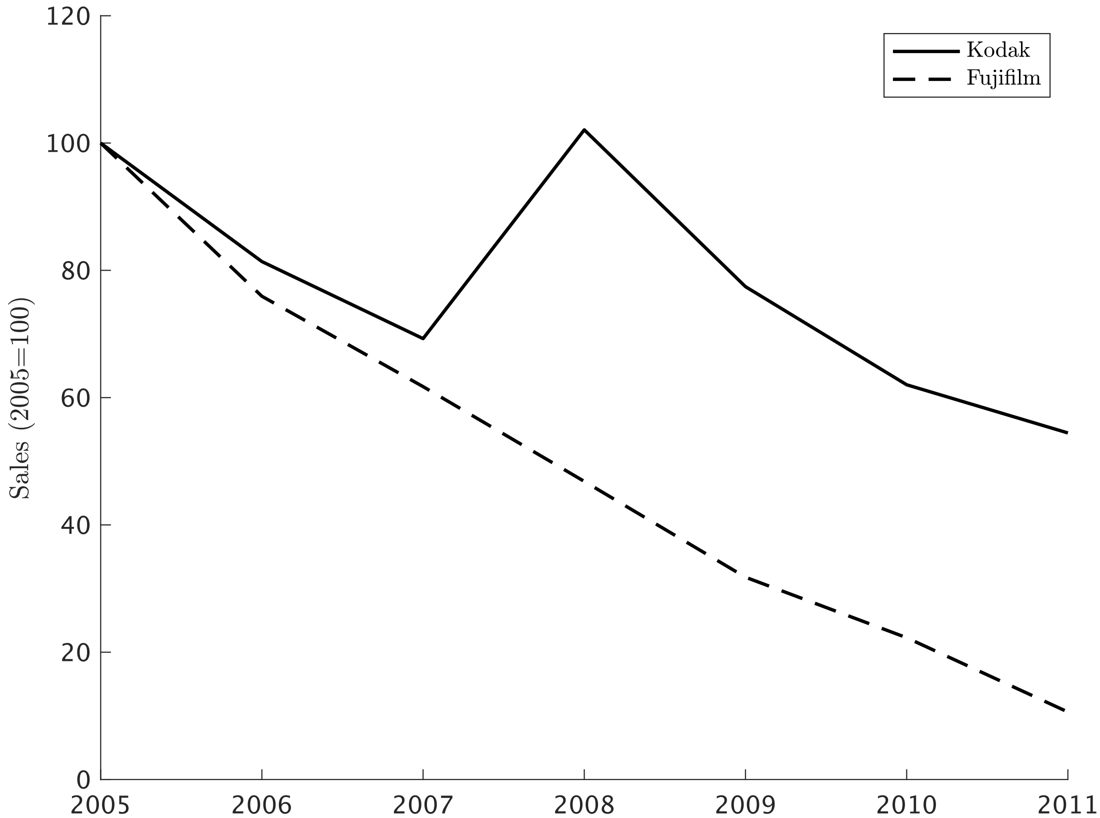

Figure 2: Sales for traditional film-related businesses of Kodak and Fujifilm

Note: The solid line shows Kodak's FPG segment sales, and the dashed line shows the sales for "color films and others" and "photofinishing equipment" in Fujifilm's Imaging Solutions segment. For comparison, both series are normalized to 100 in 2005.

For Kodak, sales for the FPG are used from 2005 to 2007, and sales for the Film, Photofinishing and Entertainment Group (FPEG) Segment are used from 2008 to 2011. We use the values from Kodak's 2007, 2010, and 2011 annual reports (each has data for the last three years), which are consistent with Kmia (2022).

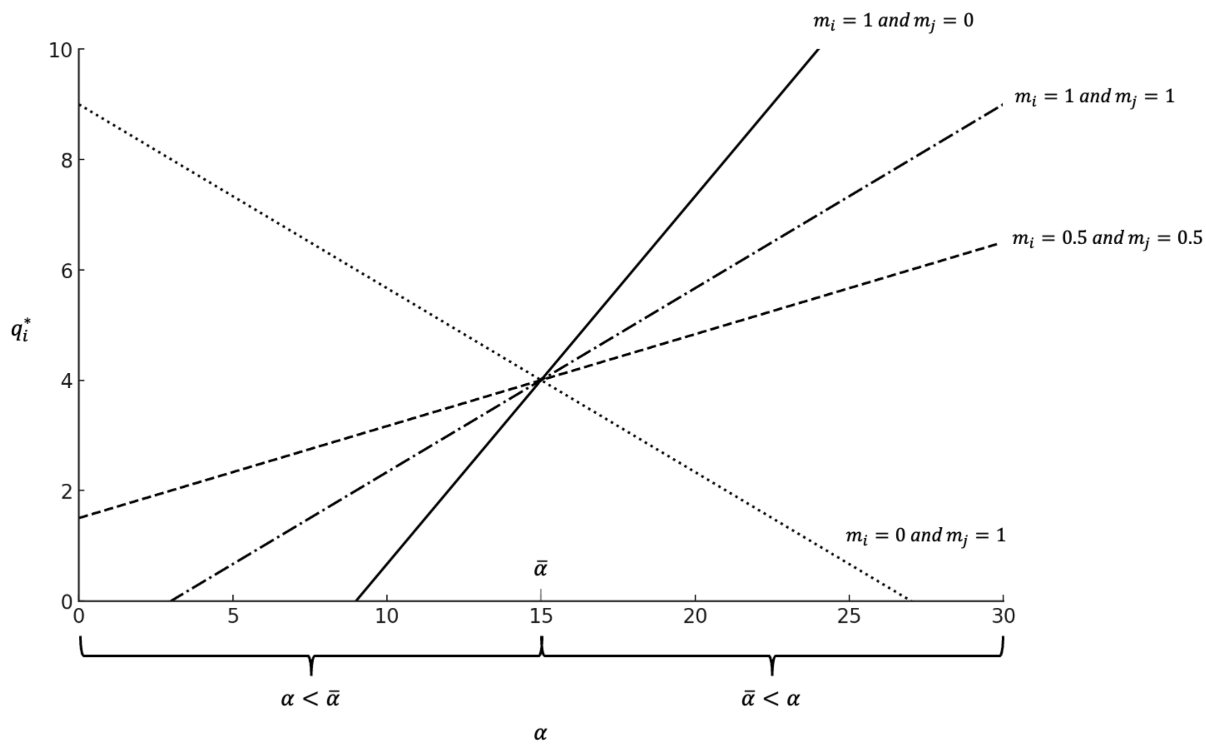

Figure 3: The relationship between market size and equilibrium quantity

Note: This figure plots firm i's equilibrium quantity (q_i^*) against market size (α). The slope of each line depends on the pair of attention parameters (m_i, m_j): the full-attention benchmark ($m_i = m_j = 1$), partial attention ($m_i = m_j = 0.5$), and asymmetric attention where one firm ignores market changes ($m_i = 1, m_j = 0$ or $m_i = 0, m_j = 1$). The remaining parameters are set to $\bar{\alpha} = 15$, $\beta = 1$, and $c = 3$.

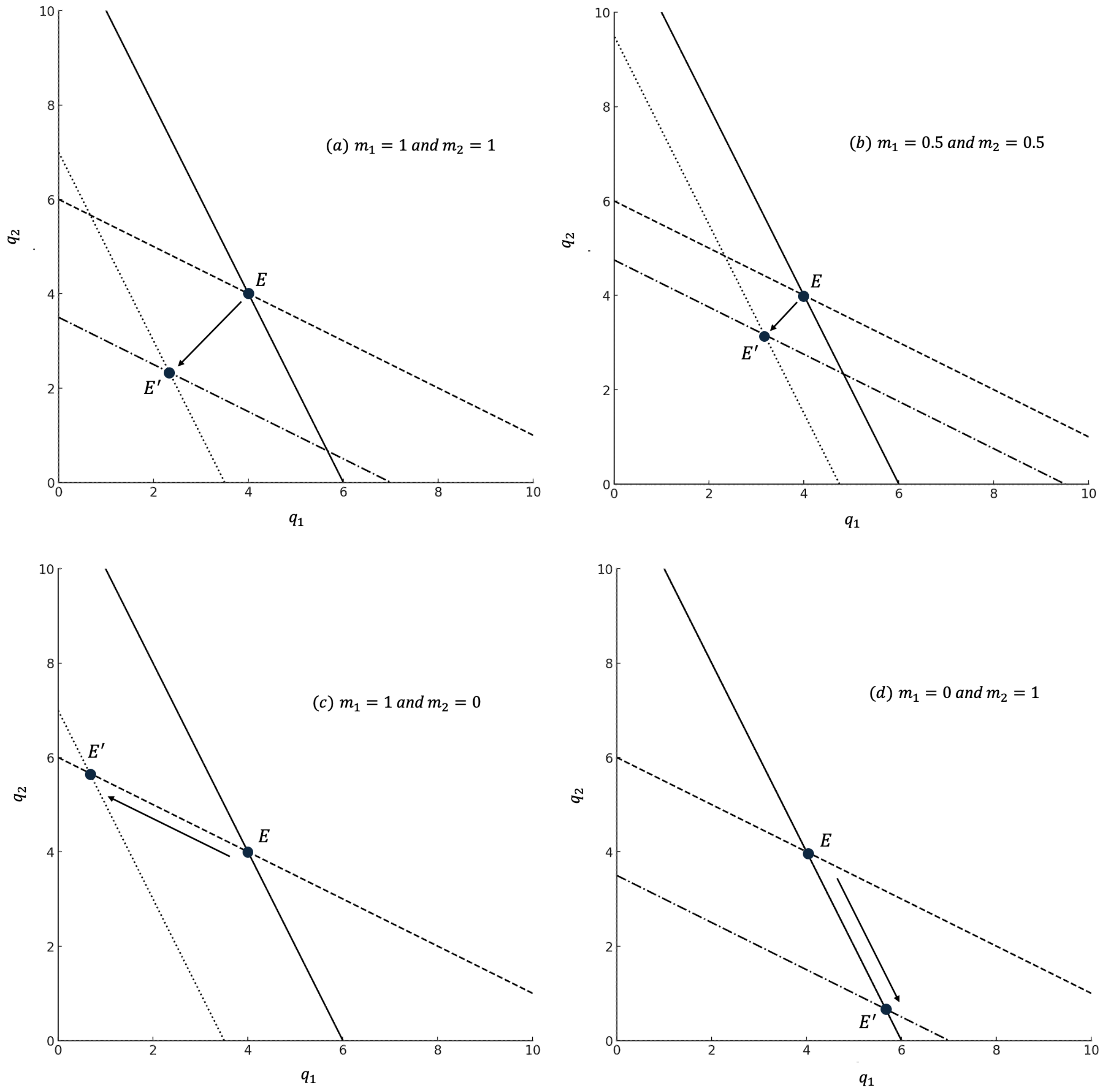

Figure 4: Reaction functions and equilibrium responses to a decline in market size

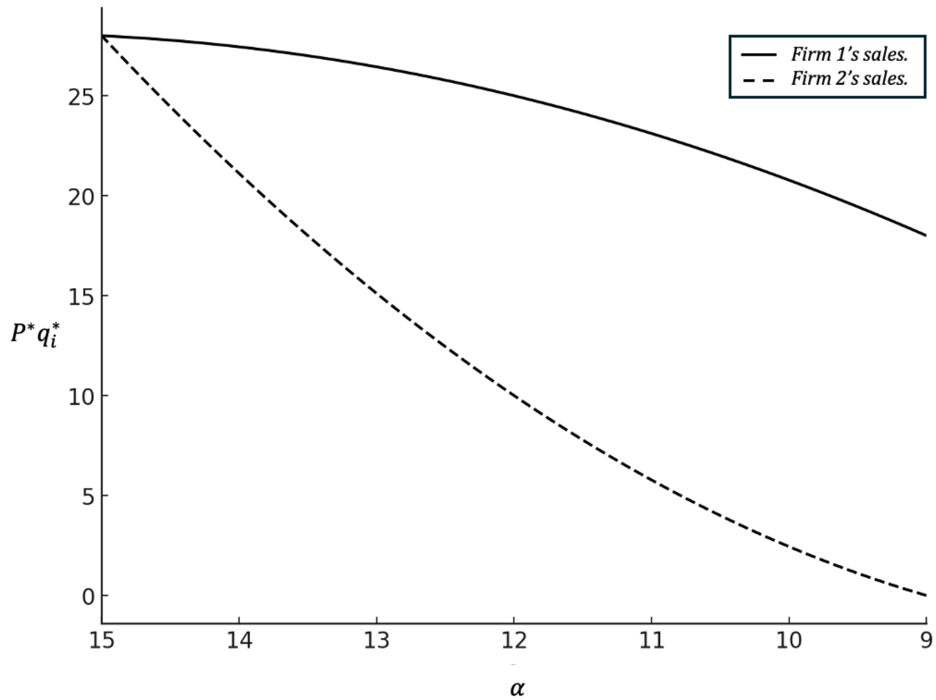

Figure 5: Sales of inattentive firm 1 and fully attentive firm 2

Note: The relationship between market size (α) and sales ($P^* q_i^*$) for two firms. The solid line shows firm 1's sales when it fully anchors on the default market size ($m_1 = 0$). The dashed line shows firm 2's sales when it pays full attention to changes in market size ($m_2 = 1$). Parameters are $m_1 = 0$, $m_2 = 1$, $\bar{\alpha} = 15$, $\beta = 1$, and $c = 3$.